Helios Mission Support

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The successful flight of the Helios-1 spacecraft continues as it approaches its third aphelion. The Helios-2 spacecraft has entered its first superior conjunction and continues in excellent health. Much valuable scientific information about the solar corona and its effects on electromagnetic waves is expected to be learned from data gathered during this superior conjunction.

I. Introduction

This is the tenth article in a series that discusses Helios-1 and -2 mission support. The previous article (Ref. 1) reported on Helios-1 third perihelion, Helios-2 first perihelion, spacecraft Traveling Wave Tube (TWT) and ranging anomalies, and Helios DSN-Spaceflight Tracking and Data Network (STDN) cross-support activities. This article covers Helios-1 cruise phase, Helios-2 first solar occultation, Helios DSN-STDN cross-support status, DSN-STDN engineering test results, and DSN performance.

II. Mission Operations and Status

A. Helios-1 Operations

Now that Helios-2 has joined Helios-1 in orbit about the sun, data (experiment) comparisons can be made at times of interest along their respective trajectories. Two points of interest occurred during this reporting period: radial line-up on 3 May 1976 and spiral line-up between 8–13 May 1976.

Radial line-up occurs when the two spacecraft and the sun lie in a straight line. This alignment is important in gathering data about solar winds that emanate from the sun in straight paths (radii) through space. The sun also emits electromagnetic waves that travel spiral paths from the sun. When the two spacecraft happen to be along one of these paths they are said to be in spiral alignment. Correlation can then be made with the magnetic experiments data.

Helios-1 is approaching its third aphelion (2 July 1976) cruise phase. It is radiating data in the high-power mode from the high-gain antenna and is operating well with one exception. The ranging transponder is inoperative (see Subsection III-B).

B. Helios-2 Operations

The Helios-2 spacecraft entered its first solar superior conjunction (sun-Earth-probe angle < 5 deg) on 4 May 1976, thereby completing its primary mission. Solar occultation (spacecraft behind the sun) occurred on 16 May. The sun-Earth-probe (SEP) angle will remain less than 5 deg until approximately 6 October 1976. This superior conjunction phase is of extreme interest to spacecraft experiments 11 and 12 (Celestial Mechanics and Faraday Rotation, respectively). Plans to gather special spacecraft telemetry and DSN performance data pertinent to these experiments have been initiated. The Helios radio science team, located at JPL, has been active in planning and coordinating special operational activities to assemble and analyze spacecraft data relative to these two experiments.

For the enhancement of certain spacecraft data, the high-power transmitter at Goldstone (DSS 14) was requested and authorized for specific dates during the superior conjunction.

Ranging data obtained by the Mu_2 ranging equipment during Helios-2 entrance into solar occultation clearly indicates the superiority of the Mu_2 over the Planetary Ranging Assembly (PRA) at small SEP angles. Due to the Helios-2 trajectory having small SEP angles until the late October 1976 second perihelion, it is highly desirable to maintain the Mu_2 system at DSS 14 until that time.

As reported in the last report (Ref. 1), the Helios-2 spacecraft had experienced TWT anomalies—"out of limit" helix current conditions—during the month of April 1976. After extensive testing by Messerschmitt-Bolkow-Blohm (MBB) and Watkins-Johnson engineers, the TWT final current limits were redefined. On April 29 at 1430 GMT, the Helios-2 TWT-2 was switched to the high-power mode and, after settling time, the TWT-2 helix and collector current values were within the newly defined limits and have since remained there.

The Helios-2 spacecraft continues to operate in a nominal manner, on high-power, high-gain antenna; it is spin stabilized at 60.53 r/min.

C. Spaceflight Tracking and Data Network (STDN) Cross-Support

The STDN-Madrid station supported project Helios from 15 January through 9 April, when the downlink signal level reached recording threshold. The STDN-Goldstone station supported from 6 April until 5 May, when support was terminated by Project management. Evaluation of the STDN-Goldstone recorded data (after processing and playback from the DSN equipment at the Spacecraft Compatibility-Monitor Station (STDN (MIL-71)) showed an average loss of approximately 8-10 dB when compared to a DSN 26-meter station. This means that the spacecraft would have to operate at 1/8 the data rate achievable at a DSN station to obtain the same data quality from analog tapes recorded at a STDN station.

According to management guidelines established before the DSN-STDN cross- support was initiated, this performance was considered marginal.

The Helios project management terminated the STDN cross-support in the analog tape record-only mode for Helios on 5 May 1976. This decision was reached at a Helios Operations Status Review conducted at JPL on 4 and 5 May 1976. The overriding reason for this decision was an announcement that the German Telecommand Station at Weilheim would be modified in the fall of 1976 to include a telemetry data receiving capability. This station would be dedicated to Helios support. The additional telemetry coverage offered by a dedicated German station, coupled with the capability to store data aboard the spacecraft for subsequent dump during a later tracking period, makes the practicality of a "record-only mode" (with its attendant losses and built-in time lag) questionable. Project management decided, however, to continue engineering tests to evaluate the use of a microwave link between an STDN and a DSN station for real-time telemetry processing and commanding. A project decision on whether to request use of the Goldstone STDN-DSN real-time microwave link configuration to support Helios perihelion operation in October 1976 was deferred until later (September), pending results of the engineering evaluation.

D. DSN-STDN Engineering Test Results

Because the Goldstone intersite microwave link used to support Apollo has been removed, the first Helios Engineering tests were conducted at Spain between STDN-Madrid and Deep Space Station (DSS) 62. Meanwhile, efforts to restore the Goldstone STDN-DSN microwave link were started.

A real-time Telemetry Engineering test was successfully performed at Madrid on 21 April 1976. After establishing the microwave configuration and adjusting levels, a 32.768-kHz subcarrier modulated with simulated Helios data was sent from DSS 62 to STDN-Madrid to modulate their test transmitter. The receiver baseband signal was returned via the microwave link and successfully processed at DSS 62 in their Telemetry and Command Data (TCD) handling equipment. This was followed on 22 April by a test that provided live Helios-1 spacecraft telemetry from STDN-Madrid via microwave for simultaneous processing and comparison with DSS 62 telemetry data. The signal-to-noise ratio (SNR) difference was a minus 8.3 dB for the STDN telemetry.

The success of the Madrid STDN-DSN real-time telemetry engineering test led to a similar test of command performance. On 27 May, the stations were configured so that the DSS 62 Command Modulator Assembly (CMA) would modulate the STDN-Madrid station's uplink carrier while the Helios downlink telemetry was received and processed by DSS 62 only. The Helios-1 spacecraft commands were generated, executed, and monitored from the German Space Operations Center (GSOC). Twenty-eight commands were successfully sent to the Helios-1 spacecraft via the STDN-Madrid transmitter.

By May 18, 1976, the Goldstone STDN-DSN combined coaxial line and microwave link had been established one-way (STDN-to-DSN). With the Madrid engineering test as a model, a real-time telemetry engineering test was performed on 3 June 1976. The Goldstone STDN, using a Block III receiver, received the Helios-1 telemetry subcarrier and forwarded this to the DSS 12 TCD. Simultaneously, DSS 12 tracked Helios-1. The STDN telemetry performance was now only 4.5 dB below the DSN, due to improvements in the STDN station configuration. Other Goldstone STDN-DSN real-time telemetry engineering tests are planned to provide more data points to evaluate the DSN-STDN real-time cross-support configuration.

Parallel studies are being made to expand the Goldstone Helios tests to include simultaneous telemetry and command capability.

E. Actual Tracking Coverage Versus Scheduled Coverage

This report covers tracking activities for a 56-day period from 12 April through 6 June 1976, for the Helios-1 and -2 spacecraft. Operations during this period include Helios-1 cruise and Helios-2 first perihelion and first solar occultation. Both spacecraft were tracked a total of 197 times for a total of 1542.4 hours. Because this time period included part of Helios- 2 prime mission and critical mission phases (perihelion and solar occultation), total Helios coverage exceeded that of Pioneer by almost 400 hours. Helios-1 was tracked 96 times for a total of 730 hours. This represented a 3-percent increase in coverage over the last report period. The average pass duration for Helios-1 was 7.6 hours compared to 5.6 hours last period. Helios-2 was tracked 101 times for a total of 812.1 hours with an average track time of 8 hours. Prime mission coverage requirements were met 100 percent. Helios-2 perihelion and occultation coverage was supported by the 64-meter stations at Canberra and Goldstone, accounting for approximately 65 percent of the total DSN Helios-2 support.

The Spaceflight Tracking and Data Network (STDN) provided 20 hours of Helios telemetry recording support this period before being terminated on 5 May 1976.

Helios-1 and -2 spacecraft, now in extended mission phase, have equal priority with Pioneers 10 and 11 spacecraft. With Viking planetary activities in the spotlight during the next few months, only limited DSN support is expected for Helios.

III. DSN System Performance

A. Command System

Owing to the Helios-2 prime mission (when the DSN provided 100 percent tracking coverage) coming to an end during mid-May, there has been a marked decrease in the number of commands radiated to the Helios spacecraft when compared to the last report period. A total of 7331 commands were processed for both Helios spacecraft. This represents a 30-percent decrease in command activity over the last report period. The cumulative command totals now stand at 36,593 for Helios-1 and 13,173 for Helios-2.

Two command system aborts were reported for April and three for May, 1976—three with Helios-1 and two with Helios-2. Three of the five aborts were associated with station transmitter failures. The other two were associated with command alarms that did not clear. Two of the aborts occurred at DSS 14, but for different reasons. This station has provided the majority of Helios-2 support since entering superior conjunction in early May. These raise the cumulative command system abort count to eleven for Helios-1 and four for Helios-2.

For the months of April and May, command system downtime dropped to 18 hours and 55 minutes, or an approximate 27-percent decrease over the last period. Only two outages exceeded one hour (the biggest being 2.5 hours). Although it does show a decrease over the last report period, command system downtime was still high when compared to earlier periods.

B. Tracking System

The Helios-1 spacecraft ranging transponder again failed to respond on 26 April 1976. This spacecraft anomaly, associated with the transponder Very Stable Oscillator (VSO) temperature, has occurred twice before (see Ref. 1). The last valid Helios spacecraft ranging data were received on 9 April 1976. This anomalous condition is expected to last until September, when the transponder VSO temperature will again come within operational limits.

With the Helios-2 spacecraft's first superior conjunction, renewed and intense interest on the part of the Helios radio science experimenters resulted in special measures to assure the quality of the ranging acquisitions. These special tests and procedures included "receiver ramping" for each DSS 14 pass during the weeks immediately before and after the first spacecraft occultation (16–17 May 1976). This was done to obtain quality ranging data at the lowest possible SEP angles. The results of these efforts were that valuable ranging data were obtained at a lower SEP angle than before—less than 0.9 deg.

C. Telemetry System

Helios-2 entered its first solar conjunction on DOY 125, May 4, 1976, (SEP angle < 5.1 deg) and will exit on DOY 280, 6 October 1976. This mission period holds special interest to experiments 11 and 12 and also to the DSN. The DSN's interest lies in the answers to two questions: (1) what is the increase in system noise temperature due to the small SEP angles, and how does it compare to past solar conjunctions? and (2) to what extent are the signal level (AGC) and signal-to-noise-ratio (SNR) affected by the small SEP angles, how well can this be predicted, and what radio frequency (RF) and SDA bandwidths are best for minimizing degradation? To provide answers to these questions, special data types are being collected. The first type of data consists of special system noise temperature chart recordings; the second type is the results of spectral broadening tests. A plan (Table 1) to gather and analyze these data types was instituted and shall continue throughout the solar conjunction period (4 May through 6 October 1976).

Based on analysis of similar data collected during Helios-1 and -2, inferior conjunction (Ref. 1) predictions of the signal level and SNR were made through 1 July 1976. A preliminary "quick look" analysis of May data from Helios-2 superior conjunction shows signal level and SNR degradation very close to predicted values. One exception to this is 8 bit-per-second coded data from 64-meter stations. These data have been erratic. The cause, to date, is unknown but is under investigation. A report (quick-look) of May and June data collected on the Helios-2 spacecraft superior conjunction is expected in late July 1976, from the Network Analysis Group.

Updated Helios-2 spacecraft downlink parameters, recently received from the Helios project, have been factored into the telemetry predicts program Link Analysis Prediction Program (LAPP) resulting in values closer to actual measurements. Helios-1 telemetry predicts have yet to be corrected with updated parameters.

IV. Conclusions

The Helios-1 spacecraft has continued on its trajectory recording scientific data and reading-out these data on command. The Helios-2 spacecraft completed its prime mission in which it enjoyed 100-percent tracking coverage. This prime mission, although as successful as that of Helios-1, did have its TWT anomalies. With these problems now passed, the Helios-2 spacecraft is experiencing its first superior conjunction.

The "Record Only" STDN cross-support was terminated as of 5 May 1976; however, STDN-DSN engineering tests are being performed to determine the practicality of using an STDN-DSN microwave link to send Helios spacecraft data in real time to a DSN station for processing. The results of these tests will determine if the STDN cross-support for Helios is to be requested to support the October perihelion of Helios-2. It is anticipated that the testing will be completed by 1 July 1976.

Special operational and analysis support activities to support the Helios- 2 superior conjunction mission phase are in progress and shall continue throughout. Results on some of the data analysis (DSN performance at low SEP angles) is expected within the next report period.

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Reference

1. Goodwin, P. S., "Helios Mission Support," in *The Deep Space Network Progress Report 42-33*, pp. 26–30. Jet Propulsion Laboratory, Pasadena, California, July 15, 1976.

Table 1. Helios-2 superior conjunction overview

Event	DOY	Time[a]
Begin data collection	125	(First pass)
Expected first degradation	126	
Begin blackout (first)	135	(Variable)
Minimum SEP angle (1st minimum)	137	1500Z
End blackout (first)	141	(Variable)
Begin blackout (second)	185	(Variable)
Minimum SEP angle (2nd minimum)	192	2200Z
End blackout (second)	200	(Variable)
Begin blackout (third)	267	(Variable)
Minimum SEP angle (3rd minimum)	269	1400Z
End blackout (third)	271	(Variable)
Expected end of degradation	278	
End data collection	280	(Last pass)

[a]Times are variable, depending on coverage (64-meter, or 26-meter, or STDN coverage).